United States Army School of Aviation Medicine
Fort Rucker, Alabama
JANUARY 2003

STUDENT HANDOUT

TITLE: ALTITUDE PHYSIOLOGY
FILE NUMBER: U3OO4502/ Version 1

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Altitude Physiology
U3004502 / Version 1
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Prerequisite Lesson(s)	**Lesson Number** **Lesson Title** None
Clearance Access	Security Level: Unclassified Requirements: There are no clearance or access requirements for the lesson.
Foreign Disclosure Restrictions	FD5. This product/publication has been reviewed by the product developers in coordination with the USASAM foreign disclosure authority. This product is releasable to students from all requesting foreign countries without restrictions.

References

Number	Title	Date	Additional Information
2nd Edition	Fundamentals of Aerospace Medicine	1996	
FM 3-04.301	Aeromedical Training for Flight Personnel	29 Sep 2002	
AR 95-1	Flight Regulations	01 Sep 1997	
AR 40-8	Temporary Flying Restrictions Due to Exogenous Factors	17 Aug 1976	

Student Study Assignments

Study student handout and review reference materials listed above.

Terminal Learning Objective

Action:	Manage the physiological effects of altitude.
Conditions:	While serving as an aircrew member.
Standards:	In accordance with AR 95-1, AR 40-8, FM 3.04-301, and Fundamentals of Aerospace Medicine

Safety Requirements

None.

Risk Assessment Level

Low - RISK ASSESSMENT LEVEL: Low.

Environmental Considerations

NOTE: It is the responsibility of all soldiers and DA civilians to protect the environment from damage. None.

Evaluation

On the last day of aviation medicine academics, each student will be evaluated on this block with a 50 question examination in which they must answer 35 of 50 questions correctly to receive a passing score. The test will be given in room X110 of Bldg 301.

A. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the physiological zones and the physical divisions of the atmosphere
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

a. Atmosphere:

NOTE: The biosphere is that area of our world where life can exist. It includes the atmosphere (air), hydrosphere (water) and lithosphere (earth). All of the atmosphere is not within the biosphere.

(1) Definition - a mixture of gases that surrounds the earth's surface. Consists of a mixture of water vapor and gases that extends from the surface to approximately 1,200 miles. Held in place by gravity, it exhibits few physical characteristics that can be readily observed. Additionally, it shields earth's inhabitants from ultraviolet radiation.

(2) Layers of the atmosphere.

(a) Troposphere

1. Lies closest to the earth's surface.

2. Extends to an altitude of about 30,000 feet at the poles and 60,000 feet at the equator. The difference in altitude is due to the rising heated air at the equator.

3. Domain of weather - winds, turbulence and convection. Temperature lapse rate is 2C/1000 feet.

(b) Tropopause

1. Boundary between troposphere and stratosphere.

2. It has a stable temperature and varies in width.

3. Domain of high winds and highest cirrus clouds.

4. Gradually increases in altitude from the polar regions to the equator.

(c) Stratosphere.

1. Extends upward from the tropopause to about 50 miles from the earth's surface.

2. Characterized by a constant (-55°C) temperature, an absence of water vapor, turbulence, no clouds, and jet streams.

3. Ozone layer at the top.

(d) Ionosphere.

1. Extends from the stratosphere to about 600 miles above the earth's surface. The space shuttle orbits at 160 miles above the earths surface.

2. Forms a shield around the earth and protects individuals from ultraviolet radiation.

3. Large electron density affects communications.

4. Temperature increases to 1500 C.

(e) Exosphere.

1. Extends from the ionosphere to about 1,200 miles above the earth's surface.

2. Hypothetically true space.

b. Physiological zones of the atmosphere. Man cannot physiologically adapt to all the physical changes of temperature and pressure that occur within the various regions. For this reason, the atmosphere is further divided into three physiological divisions. The primary basis for these physiological zones is the pressure changes that take place in the human body.

(1) Efficient zone.

(a) Extends from sea level to 10,000 feet.

(b) Most individuals are physiologically adapted to this zone.

(c) Oxygen levels within this zone are sufficient for a normal, healthy person without the aid of protective equipment.

(d) Barometric pressure drops from 760mm/hg to 523mm/hg in this zone.

(e) Most Army flights take place in this layer.

(2) Deficient zone.

(a) Extends from 10,000 feet to 50,000 feet.

(b) Noticeable physiological problems, such as hypoxic hypoxia and evolved gas disorders, occur unless supplemental oxygen is used.

(c) Barometric pressure drops from 523mm/hg at 10,000 feet to 87mm/hg at 50,000 feet.

(3) Space equivalent zone.

(a) Extends upward from 50,000 feet.

(b) Without an artificial atmospheric environment, this zone is lethal to humans and death will occur rapidly.

c. Composition of the atmosphere.

(1) Nitrogen (N_2): 78%. Most plentiful gas in the atmosphere. Essential building block of life, but not readily used by the body. Nitrogen saturates body cells and tissues, which may cause evolved gas disorders.

(2) Oxygen (O_2): 21%. Second most plentiful gas. The human body uses O_2 to convert body fuels into energy.

(3) Other gases: 1%. Carbon dioxide (CO_2)-contained in the other 1% of gases and is essential to controlling respiration. (.03% of that 1% is CO_2.)

B. ENABLING LEARNING OBJECTIVE

ACTION:	Select the correct barometric pressure at sea level.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3-04-301.

a. Atmospheric (barometric) pressure. Definition - the measurement of pressure exerted on the earth's surface from the gases and water in the atmosphere.

b. It is an observable characteristic that can be expressed in PSI, mm/Hg, inches of Hg, or in feet as indicated by an altimeter.

c. The percentage of Nitrogen (78%), Oxygen (21%), and Other gases (1%) in the atmosphere remains constant but pressure decreases with altitude. This decrease in pressure is responsible for most physiological problems in flight.

d. Standard sea level atmospheric pressure is 760mm/Hg. At 18,000 feet this atmospheric pressure is reduced to 380mm/Hg or one-half the pressure found at sea level. The chart shows other significant altitudes and atmospheric pressure reductions.

ALTITUDE	PRESSURE	
FEET	mm/Hg	ATMOSPHERES
18,000	380	½
34,000	190	¼
48,000	95	1/8
63,000	47	1/16

e. Dalton's Law of partial pressure.

(1) Definition - the pressure exerted by a mixture of gases is equal to the sum of the partial pressures of each gas in the mixture.

<u>NOTE</u>: While the law states that atmospheric pressure is the sum of pressures of the gases in it, it also means that if the total pressure is decreased, the pressure

of each gas must also decrease.
(2) Significance.

(a) The total atmospheric pressure exerted on the body decreases with altitude.

(b) The partial pressure of oxygen decreases with increased altitude.

(c) The amount of O_2 in a given volume of air decreases with altitude.

C. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the components of the circulatory system that transport oxygen throughout the human body.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301

a. Functions of the circulatory system.

(1) Transport oxygen and nutrients (fuels) to cells throughout the body.

(2) Transport metabolic waste products to organ removal sites.

(3) Assists in temperature regulation.

b. Components of the circulatory system.

(1) Arteries - vessels that transport oxygenated blood from the heart to the body.

(2) Veins - vessels that transport deoxygenated blood from the body to the heart.

(3) Capillaries.

(a) Connect arteries to veins.

(b) Contact most tissues of the body transferring O_2, nutrients CO_2, and waste products between the cells and blood.

(c) Walls of the capillaries are one cell thick.

(d) Gas diffusion takes place between the body tissues and the blood.

c. Components and functions of blood – The average individual has 10 pints of blood which is approximately 5% of total body weight.

(1) Plasma: 55% of whole blood.

(a) Fluid part of the blood composed mainly of salt, water, and proteins.

(b) One of its important functions is to transport CO_2 in the blood.

(2) White blood cells (WBCs or leukocytes).

(a) Differ from red blood cells in that they contain no hemoglobin.
(b) Main function is to fight infection or inflammation.

(3) Platelets (Thrombocytes).

(a) Small irregular shaped bodies produced by the bone marrow.

(b) Aid in blood coagulation and maintaining the circulatory system.

(4) Red blood cells (RBCs or erythrocytes).

(a) Have an iron-containing compound, hemoglobin, which is responsible for the O_2 uptake of these cells.

(b) Transport approximately 98.5% of all O_2 in the body; the rest is transported in solution within the plasma.

(c) Bright red color of arterial blood results from the combination of O_2 with hemoglobin; darker color of venous blood reflects a hemoglobin that has no O_2 attached to it.

(d) Produced in the bone marrow and the number RBCs that an individual has depends largely on their environment. Such factors as the altitudes at which a person lives and whether a person smokes will influence RBC reproduction.

D. ENABLING LEARNING OBJECTIVE

ACTION:	Select the functions and types of respiration.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

a. Respiration. Definition - process by which a living organism exchanges gases with its environment.

b. Functions.

(1) Provide oxygen to the cells of the human body.

(2) Remove carbon dioxide from the cells of the human body.

(3) Assists in maintaining body temperature.

(4) Assists in maintaining body acid-base balance.

c. Types of respiration (external and internal).

(1) External respiration - lungs are ventilated during inhalation and exhalation, and gases are transferred through the lungs into the blood stream.

(a) Phases of external respiration - the respiratory cycle is an involuntary process that continues unless a conscious effort is made to control it.

There are two phases of external respiration:

1. Active phase – the movement of air into the lungs (inhalation) is known as the active phase. During inhalation the chest wall expands and the diaphragm moves downward creating an area of lower pressure inside the lungs. With a higher pressure outside the lungs the law of gaseous diffusion takes place and the lungs fill with air.

2. Passive phase – the movement of air from the lungs (exhalation) is known as the passive phase. During exhalation the diaphragm relaxes and the chest walls contract increasing pressure inside the lungs. Once the glottis is opened, the pressure causes the air to rush out, releasing CO_2 into the atmosphere.

(b) Components of the external respiratory system.

1. Oral-nasal passage.

a. Includes the mouth and nasal cavities.

b. Nasal cavity contains many fine, ciliated hair cells which filter particles from the air upon inhalation. Therefore, air that enters through the nasal cavity is cleaner than air that enters through the mouth.

2. Pharynx.

a. Back of the throat and is connected to oral-nasal cavity and the trachea.

b. Humidifies and warms the air entering the respiratory system.

3. Trachea (Windpipe).

a. Tube through which air moves down into the bronchi.

b. From here, air continues to move down through the bronchi and increasingly smaller passages, or ducts, until it reaches the alveoli.

c. Also aids in expulsion or swallowing of mucus moved there by cilia.

(2) Internal respiration - gases are transported to and from body tissues by the blood. Chemical changes take place within the alveoli and tissue cells to metabolize the oxygen.

(a) Alveoli.

1. Small sacs surrounded by a network of capillaries.

2. There are approximately 300 million alveoli in a pair of human lungs.

3. Actual site of oxygen and carbon dioxide exchange between the respiratory and circulatory systems.

(b) Law of Gaseous Diffusion - this law states that a gas moves from an area of high pressure to an area of lower pressure.

(c) Blood gas exchange.

1. When O_2 reaches the alveoli, it crosses a thin cellular barrier and moves into the capillary to reach the RBC. As the O_2 enters the alveoli, it has a partial pressure (PO_2) of about 100mm/Hg. Within the blood the PO_2 of the venous blood is about 40mm/Hg. As the blood flows through the capillary the O_2 moves from the area of high pressure within the alveoli to the area of lower pressure within the blood. Therefor O_2 saturation of RBCs takes place.

2. CO_2 diffuses from the blood to the alveoli in the same manner. The PO_2 in the venous blood is around 46mm/Hg in the alveoli. As the blood moves through the capillaries, the CO_2 moves from the high PCO_2 in the capillaries to an area of lower PCO_2 in the alveoli. The CO_2 is then exhaled during the next passive phase of respiration (exhalation).

3. The amount of O_2 transferred across the alveolar-capillary membrane into the blood depends primarily on the alveolar pressure of O_2 in relation to the venous pressure of O_2. O_2 transport in the blood is a pressure dependent phenomena.

4. This pressure differential is critical to the crewmember, because O_2 saturation in the blood decreases as altitude increases due to the decreasing partial pressure of oxygen in the atmosphere.

5. This decrease in O_2 saturation can lead to hypoxia.

d. Control of respiration.

(1) Controlled by the respiratory centers in the pons and medulla oblongata (lower brain)

(2) The uptake of O_2 and CO_2 takes place through extensive chemical changes in the hemoglobin and plasma of the blood.

(3) If the chemical pathways are disrupted, the chemical balance of the body changes.

(4) Normal pH level in the body is approximately 7.4 (slightly alkaline).

(5) During respiration, the CO_2 elevates, the acidity level increases, and the pH value lowers to less than 7.4.

(6) Conversely, too little CO_2 causes the blood to become more alkaline and the pH value to rise.

(7) Since the human body maintains equilibrium within narrow limits, any shift in the blood pH and CO_2 levels is sensed by the respiratory center of the brain.

(8) When unusual levels occur, chemical receptors trigger the respiratory process to help return the CO_2 and pH level to normal limits.

E. ENABLING LEARNING OBJECTIVE

ACTION:	Match the types of hypoxia with their respective causes.
CONDITIONS:	Given a list of hypoxia types and a list of hypoxia causes.
STANDARDS:	IAW FM 3.04-301.

a. Hypoxia. Definition - a condition that results from an insufficient amount of oxygen (O_2) in the body.

b. Types of hypoxia.

(1) Hypemic hypoxia - caused by a reduction in the O_2-carrying capacity of the blood. Anemia and blood loss are the most common cause of this type. Carbon monoxide from smoking and exhaust fumes are potentially dangerous to the aviator. Nitrates and sulfa drugs also cause this type by forming compounds with hemoglobin that block its ability to attach O_2 for transport.

(2) Stagnant hypoxia - reduction in systematic blood flow or regional blood flow. Such conditions as heart failure, shock and the venous pooling of blood encountered during positive-G maneuvers predispose the individual to stagnant hypoxia. In addition, environmental extremes, prolonged sitting and restrictive clothing can produce local stagnant hypoxia.

(3) Histotoxic hypoxia - results when there is interference with the use of O_2 by body tissues. Alcohol, narcotics, carbon monoxide and certain poisons such as nicotine and cyanide interfere with the cells' ability to use an otherwise adequate supply of O_2.

(4) Hypoxic hypoxia - occurs when there is insufficient O_2 in the air that is breathed or when conditions prevent the diffusion of O_2 from the lungs to the blood stream. This is the type that is most likely to be encountered at altitude. It is due to the reduction of the PO_2 at high altitudes. See the chart in paragraph d under ELO #2.

c. Signs and symptoms.

(1) Symptoms are observable by the individual air crewmember. They vary from one person to the next, and are therefore considered subjective in nature. Examples include, but are not limited to the following:

(a) Air hunger or breathlessness.

(b) Apprehension (anxiety).

(c) Fatigue.

(d) Nausea.

(e) Headache.

(f) Dizziness.

(g) Hot and cold flashes.

(h) Euphoria.

(i) Belligerence (anger).

(j) Blurred vision.

(k) Tunnel vision.

(l) Numbness.

m) Tingling.

(n) Denial.

(2) Signs are observable by the other air crew members and therefore, are considered objective in nature. Examples include but are not limited to the following:

(a) Increased rate and depth of breathing.

(b) Cyanosis.

(c) Mental confusion.

(d) Poor judgment.

(e) Loss of muscle coordination.

(f) Unconsciousness.

g) Slouching.

d. Stages of hypoxia.

(1) Indifferent stage.

(a) Altitude - sea level to 10,000 feet (equivalent altitude with 100% O_2 - 34,000 to 39,000 feet) with ambient barometric pressure.

(b) Symptom – the only significant effect of mild hypoxia in this stage is that night vision deteriorates at about 4,000 feet. The retina of the eye and the central nervous system have a great requirement for oxygen. To begin compensating for this your heart and breathing rate increase at about 4000

feet to improve circulation to brain and heart.
(c) Decrease of visual sensitivity of up to 28% at 10,000 feet, and it varies among individuals.

(d) Hemoglobin saturation - 98% at sea level decreasing to 87% at 10,000 feet.

(2) Compensatory stage. The circulatory system, and to a lesser degree, the respiratory system, provide some defense against hypoxia in this stage. Examples are increases in pulse rate, systolic blood pressure, circulation rate, and cardiac output.

(a) Altitude--10,000 feet to 15,000 feet (equivalent altitude with 100% O_2 – 39,000 feet to 42, 000 feet) with ambient barometric pressure.

(b) Symptoms.

CAUTION: Failure to recognize symptoms and take corrective action may result in an aircraft mishap.

1. Impaired efficiency.

2. Drowsiness.

3. Poor judgment.

4. Decreased coordination.

(c) Hemoglobin saturation - 87% to 80%.

(3) Disturbance stage. In this stage, the physiological responses can no longer compensate for the O_2 deficiency.

(a) Altitude - 15,000 feet to 20,000 feet (equivalent altitude with 100% O_2 – 42,000 feet to 44,800 feet) with ambient barometric pressure.

(b) Symptoms.

CAUTION: Failure to recognize symptoms and take corrective action may result in an aircraft mishap.

1. Sensory.

a. Vision - peripheral and central vision are impaired and visual acuity is diminished.

b. Touch and pain - diminished or lost.

c. Hearing - one of the last senses to be lost.

2. Mental - intellectual impairment is an early sign that often prevent an individual from recognizing disabilities.

a. Memory.

b. Judgment.

c. Reliability.

d. Understanding.

e. Decision making/problem solving.

3. Personality - may be a release of basic personality traits and emotions as with alcohol intoxication.

a. Euphoria.

b. Aggressiveness.

c. Overconfidence.

d. Depression.

4. Performance (psychomotor functions).

a. Coordination.

b. Flight control.

c. Speech.

d. Handwriting.

(c) Signs.

1. Hyperventilation.

2. Cyanosis.

(d) Hemoglobin saturation - 65-80%.

(4) Critical stage. Within 3 to 5 minutes, judgment and coordination deteriorate.

(a) Altitude - 20,000 feet and above (equivalent altitude with 100% O_2 – 44,800 feet and above) with ambient barometric.

(b) Signs.

1. Loss of consciousness.

2. Convulsions.

3. Death.

(c) Hemoglobin saturation--less than 65%.

WARNING: When hemoglobin saturation falls below 65%, serious cellular dysfunction occurs; and if prolonged, can cause death.

e. Factors modifying hypoxia symptoms.

NOTE: The factors increasing the chance of hypoxia are crucial in the academic development of the new aviator.

(1) Pressure altitude - determines the PO_2 in the lungs.

(2) Rate of ascent - at rapid rates, high altitudes can be reached before serious symptoms are noticed.

(3) Time at altitude (exposure duration) - usually the longer the duration of exposure, the more detrimental the effect of hypoxia. The higher the altitude, the shorter the exposure time required before hypoxia symptoms occur.

(4) Temperature - exposure to cold weather extremes reduces the tolerance to hypoxia by the natural increase in the metabolic workload. Therefore, hypoxia may develop at lower altitudes than usual.

(5) Physical activity - when physical activity increases, the body demands a greater amount of O_2. This increased O_2 demand causes a more rapid onset of hypoxia.

(6) Individual factors - an individual's susceptibility to hypoxia is greatly influenced by metabolic rate, diet, nutrition, and emotions (probably most inconsistent factor).

(7) Physical fitness - an individual who is physically conditioned will normally have a higher tolerance to altitude problems than one who is not. Physical fitness raises an individual's tolerance ceiling.

(8) Self-imposed stresses - smoking and alcohol increase an individual's physiological altitude and therefore reduces their tolerance ceiling.

f. Expected Performance Time (EPT) - The time a crewmember has from the interruption of the O_2 supply to the time when the ability to take corrective action is lost.

(1) The EPT varies with the altitude at which the individual is flying.

ALTITUDE	EPT
FL 500 & Above	9 - 12 seconds
FL 430	9 - 12 seconds
FL 400	15 - 20 seconds
FL 350	30 - 60 seconds
FL 300	1 - 2 minutes
FL 280	2½ - 3 minutes
FL 250	3 – 5 minutes
FL 220	8 - 10 minutes
FL 180	20 - 30 minutes

(2) Physical exertion results in a greater demand for O_2 and shortens the EPT.

(3) EPT for a crewmember flying in a pressurized cabin is reduced approximately one-half following loss of pressurization such as in a rapid decompression (RD).

g. Prevention of hypoxia (hypoxic).

(1) Limit time at altitude (AR 95-1, pg. 32, para. 8-7).

(2) Use supplemental O_2.

(3) Use pressurized cabin.

(4) Minimize self-imposed stressors.

h. Treatment of hypoxia.

(1) 100% O_2.

(2) Descend to a safe altitude (below 10,000ft at a minimum).

F. ENABLING LEARNING OBJECTIVE

ACTION:	Select the symptoms and treatment of hyperventilation.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301 and Fundamentals of Aerospace Medicine.

a. Hyperventilation - Definition - an excessive rate and depth of respiration leading to abnormal loss of CO_2 from the blood.

b. Causes.

(1) Emotions.

(a) Fear.

(b) Apprehension.

(c) Excitement.

(2) Pressure breathing.

(3) Hypoxia.

c. Symptoms--similar to those of hypoxia.

(1) Tingling sensations.

(2) Muscle spasms.

(3) Hot and cold sensations.

(4) Visual impairment.

(5) Dizziness.

(6) Unconsciousness.

d. Significance of hyperventilation.

(1) Can incapacitate a healthy crewmember.

(2) Can be confused with hypoxia.

e. Prevention.

(1) Don't panic.

(2) Control rate and depth of respiration.

f. Distinguishing between hyperventilation and hypoxia.

(1) Above 10,000 feet--assume hypoxia and treat accordingly.

(a) 100% O_2--if available.

(b) Descend to a safe altitude.

(2) Below 10,000 feet--assume hyperventilation and treat accordingly. Voluntary reduction in rate and depth of respiration is necessary to accomplish this task. Reading or repeating a checklist in most cases can treat hyperventilation.

G. ENABLING LEARNING OBJECTIVE

ACTION:	Select the causes and treatment of an ear, sinus and tooth trapped gas dysbarism.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

a. Dysbarism - syndrome resulting from the effects, excluding hypoxia, of a pressure differential between ambient barometric pressure and the pressure of gases in the body. Also referred to as disorders.

b. Trapped gas dysbarism.

(1) Boyle's Law - The volume of a gas is inversely proportional to its pressure, temperature remaining constant.

(2) Dry gas conditions - Under dry gas conditions, the atmosphere is not saturated with moisture. Basically, under conditions of constant temperature and increased altitude, the volume of a gas expands as pressure decreases.

(3) Wet gas conditions - Gases within the body are saturated with water vapor. Under constant temperature and at the same altitude and barometric pressure, the volume of a wet gas is greater than the volume of

(4) Types of trapped gas disorders.

(a) Trapped gas disorders of the gastrointestinal tract.

1. Mechanism - the stomach and intestines contains gas, which expands during ascent causing gas pains.

2. Prevention.

a. Watch your diet (if a crewmember has difficulty relieving abdominal gas pains the diet should be adjusted to avoid gas-producing foods).

b. Avoid carbonated beverages and large amounts of water before going to altitude.

c. Don't chew gum during ascent.

d. Keep regular bowel habits.

3. Treatments.

a. Belching.

b. Passing flatus.

c. Descent to a lower altitude (if pain persists).

(b) Ear blocks.

1. Mechanism.

a. As the barometric pressure is reduced during ascent, the expanding air in the middle ear is intermittently released through the eustachian tube.

b. As the inside pressure increases, the eardrum bulges until an excess pressure of approximately 12 to 15mm/Hg is reached.

c. At this time, a small bubble of air is forced out of the middle ear and the eardrum resumes its normal position.

d. During ascent, the change in pressure within the ear may not occur automatically.

e. With the increase in barometric pressure during descent, the pressure of the external air is higher than the pressure in the middle ear and the eardrum is forced inward.

f. If the pressure differential increases appreciably, it may be impossible to open the eustachian tube. The eardrum could rupture because the eustachian tube can't equalize the pressure.

2. Prevention.

a. The most common complaint of crewmembers is the inability to ventilate the middle ear.

b. This inability frequently occurs when the eustachian tube or its opening is swollen shut as the result of an inflammation or infection due to a head cold, sore throat, middle ear infection, sinusitis, or tonsillitis.

c. Unless absolutely necessary, crew members with colds or sore throats should not fly.

3. Treatment.

a. Stop descent of aircraft and attempt to clear by valsalva.

b. If the condition is not cleared, climb to altitude until cleared by pressure change or valsalva.

c. Reduce rate of descent and equalize ear/sinus frequently during descent.

(c) Sinus blocks.

1. Mechanism.

a. Like the middle ear, sinuses can also trap gas during flight.

b. Sinuses are air-filled, relatively rigid, bony cavities lined with mucus membranes.

c. Sinuses are connected with the nose by means of one or more small openings.

d. If the openings into the sinuses are normal, air passes into and out of these cavities without difficulty and pressure equalizes.

e. If these openings become obstructed it may become difficult or impossible to equalize the pressure.

2. Prevention.

a. Avoid flying with a cold or congestion.

b. Perform the Valsalva maneuver more frequently.

3. Treatment – treat a sinus block the same as you would treat an ear block.

(d) Barodontalgia (trapped gas disorders of the teeth).

1. Mechanism - change in barometric pressure can cause a toothache.

EXAMPLE: Air may be trapped in the tooth by recent dental work. Air under the filling material will expand during ascent causing pain.

2. Prevention--avoid flying following dental restoration or when in need of restoration.

3. Treatment - descent usually brings relief.

4. Referred pain.

a. Nerve endings for sinuses and the upper teeth are in close proximity in the maxilla.

b. On occasion, the sinuses will block putting pressure or pain on the upper teeth.

c. Condition must be treated as a ear/sinus block.

H. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the types and treatments of evolved gas dysbarisms, which occurs with altitude.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301 and Fundamentals of Aerospace Medicine.

a. Evolved Gas Dysbarism (decompression sickness) - Occur as a direct result of a reduction in atmospheric pressure. As pressure decreases, gases dissolved in body fluids are released as bubbles. This will cause varied skin and muscle symptoms and possibly neurological symptoms.

b. Henry's Law - The amount of gas dissolved in a solution is directly proportional to the pressure of the gas over the solution. This is similar to gas being held under pressure in a soda bottle. When the cap is removed, the liquid inside is exposed to a lower pressure; therefore, gases escape in the form of bubbles. Nitrogen (N_2) in the blood behaves in the same manner.

c. Mechanism.

(1) Inert gases in body tissues (principally N_2) are in pressure equilibrium with the same gases in the atmosphere.

(2) When barometric pressure decreases, the partial pressures of atmospheric gases decrease proportionally, leaving the tissues temporarily supersaturated.

(3) Responding to the supersaturating, the body attempts to establish a new equilibrium by ransporting the excess gas volume in the venous blood to the lungs.

(4) However, this is an inefficient system of removal and could lead to an evolved gas disorder.

d. Four types of evolved gas disorders.

WARNING: Evolved gas disorders are considered serious and medical treatment/advice must be sought immediately.

(1) Bends.

(a) Occurs when the N_2 bubbles become trapped in the joints. At the onset of bends, pain may be mild but it can become deep, gnawing, penetrating, and eventually intolerable.

(b) Severe pain can cause loss of muscular power of the extremity involved and, if allowed to continue, may result in bodily collapse.

(c) The larger joints, such as the knee or shoulder, are most frequently affected. The hands, wrists, and ankles are also common sites.

(d) It may occur in several joints simultaneously and worsen with movement.

(2) Paresthesia (creeps/tingles).

(a) Tingling and itching sensations on the surface of the skin are the primary symptoms of parathesia. It is caused by N_2 bubbles forming along the nerve tracts leading to the affected areas.

(b) A mottled red rash may appear on the skin.

(3) Chokes.

(a) Symptoms occurring in the thorax are probably caused by innumerable small N_2 bubbles that block the smaller pulmonary vessels.

(b) At first, a burning sensation is noted under the sternum. As the condition progresses, the pain becomes stabbing with deep inhalation. The sensation in the chest is similar to what one experiences after completing a 100-yard dash. Short breaths are necessary to avoid distress.

(c) There is an uncontrollable desire to cough, but the cough is ineffective and nonproductive.

(d) Finally, there is a sensation of suffocation; breathing becomes more shallow and the skin has a bluish coloration.

(4) CNS disorder.

(a) In rare cases when aircrews are exposed to high altitude, symptoms may indicate that the brain or the spinal cord is affected by N_2 bubble formation.

(b) The most common symptoms are visual disturbances, which vary from blind spots to the flashing or flickering of a steady light.

(c) Other symptoms may be a dull-to-severe headache, partial paralysis, the inability to hear or speak, and the loss of orientation.

(d) Paresthesia, or one-sided numbness and tingling, may also occur.

e. Influential factors - evolved gas disorders do not happen to everyone who flies. Certain factors tend to increase the chance of evolved gas problems and reduce the altitude at which problems can occur.

(1) Rate of ascent - the more rapid the rate of ascent, the greater the chance that evolved gas disorders will occur; the body does not have time to adapt to the pressure changes.

(2) Altitude – there is no reliable evidence for the occurrence of DCS with altitude exposures below 18,000 feet, as altitudes increase so does the rate of incidence.

(3) Age - evidence suggests that individuals in their mid-forties are more susceptible than those in their early twenties.

(4) Exercise – the effect of exercise on the incidence of DCS is equivalent to increasing the exposure altitude 3,000-5,000 feet.

(5) Duration of exposure - the longer the exposure, especially above 18,000 feet, the more likely that evolved gas disorders will occur.

(6) Repeated exposure - the more often individuals are exposed to altitude above 18,000 feet (without pressurization), the more they are predisposed to evolved gas disorders.

(7) Gender/Body build – due to emotional and political factors, studies are limited and are therefore inconclusive regarding gender and the incidence of DCS. In addition there is no scientific validation that obesity increases the rate of incidence of DCS.

f. Prevention.

(1) Denitrogenation (prebreathing 100% O_2 is required for flights exceeding 20,000 feet).

(2) Flying a pressurized aircraft, if possible.

(3) Limit time at high altitude.

g. Treatment.

(1) Descend to ground level.

(2) 100% O_2.

(3) Seek medical advice/assistance.

(4) Compression therapy.

h. Aircrew restrictions.

(1) In accordance with (IAW) AR 40-8, crewmembers will not fly for 24 hours after SCUBA diving.

(2) During SCUBA diving, excessive N_2 uptake by the body occurs in using compressed air.

(3) Flying at 8,000 feet within 24 hours after SCUBA diving at 30 feet subjects an individual to the same factors a non-diver faces when flying unpressurized at 40,000 feet. N_2 bubbles form in the circulatory system.